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13. ABSTRACT *(Maximum 200*

Sixteen fresh human cadavers were intubated while recording cervical motion using a cinefluoroscopic technique. Segmental cervical motion from the occiput through C5 was measured in both the intact spine and following the creation of a C4-5 posterior-ligamentous injury in all cadavers. Each intubation was performed using no external stabilization, Gardner-Wells traction and manual in-line cervical immobilization. The cadaveric spine motion accurately reflected previously reported segmental motion in living patients. Traction decreased craniovertebral junction motion, but neither traction nor immobilization reduced motion at the destabilized C4-5 level. Four patients without significant cervical pathology and normal motion of flexion/extension views underwent fluoroscopic monitoring during intubation without and with traction. The traction was applied by hand using Gardner-Wells tongs. One patient could not be intubated safely while traction was administered. Although we have not yet studied enough subjects to do a statistical analysis, the data compare very favorably with that from the cadaver study. Traction during intubation decreases motion of all cervical segments in live patients, with the C2-C3 and C4-C5 levels most affected.

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N. C. Draynelo MD 1/24/98

PI - Signature Date

TABLE OF CONTENTS

INTRODUCTION

The goal of emergency airway management in patients with suspected cervical injuries is to secure the airway as quickly as possible without worsening the patient's neurologic condition. Current Advanced Trauma Life Support guidelines recommend orotracheal intubation with manual in-line cervical immobilization, although nasotracheal intubation may be considered in the spontaneously breathing patient depending on the skill of the caregiver.[1] There is conflicting evidence whether blind nasotracheal intubation reduces cervical motion[2,6,7,9], and it is less reliable and more time-consuming than the orotracheal approach.[5,10,16,17] This technique is also associated with a substantial incidence of complications, including epistaxis, vomiting, aspiration, and retropharyngeal laceration,[5,8,10,23] and is best performed in cooperative patients.

The data documenting the efficacy of any method in reducing cervical movement during intubation are limited. Most published studies focus on movement of the intact spine, but very little work has been done on motion of the unstable cervical spine during intubation.[15] Although a few reports have focused on the motion of a single unstable level[3,6,7] no previous investigation has quantified segmental motion during intubation of the injured cervical spine and the effect of commonly used stabilization procedures on that motion.

Our group has previously demonstrated that in living patients with intact cervical spines the majority of motion occurs at the craniovertebral junction, followed by the atlantoaxial junction, with only a minor contribution from the subaxial spine.[20] Our early work did not address the effects of stabilization or instability on cervical motion during intubation. Given the minimal contribution of the subaxial cervical spine to the motion of intubation in the normal condition, the question arises as to what effect increased subaxial instability has on overall motion and how do stabilization maneuvers limit this motion.

BODY

We had proposed testing our hypotheses by performing 6 specific projects, two in each year of the study. In the 1997-98 year we examined cervical motion during orotracheal intubation in cadavers without and with traction, immobilization, and a hard cervical collar. Although we had anticipated studying only 6 cadavers, we were able to obtain data from 16. Cervical motion was evaluated during orotracheal intubation in cadavers before and after creation of a significant posterior ligamentous disruption. We also evaluated cervical motion during orotracheal intubation in patients without and with cervical traction. It had been anticipated that we would be able to study 10 patients in the first year, but we were only able to enroll four. The details of both of these studies follow.

CADAVER STUDY

Experimental Methods

Sixteen fresh human cadaveric subjects, including seven males and nine females ranging in age from 50 to 89 years, were used for this study. All subjects had intact cervical spines and were evaluated under fluoroscopy and found to have a normal range of motion prior to intubation. Each subject was placed supine on a flat surface and a routine direct laryngoscopy and orotracheal intubation was performed in all cases using a #3 Macintosh blade and a wire-reinforced endotracheal tube. Exposure of the glottis was limited to that necessary to allow passage of the endotracheal tube through the vocal cords under direct visualization. The same procedure was used for each method of stabilization in the intact as well as the posterior ligament-disrupted subjects. Minimal visualization was intentional to produce minimal cervical movement as would be done in a trauma situation. All intubations were performed by a single, experienced faculty anesthesiologist.

Procedure

Each subject was intubated serially while applying no external stabilization, manual in-line cervical immobilization then traction. A neurosurgeon performed all stabilization maneuvers for all intubations. For traction, Gardner-Wells tongs were placed and force was exerted throughout the intubation procedure by hand until the neurosurgeon felt that it was a proper amount based on clinical experience. Force was measured with a spring-gauge scale and ranged from 7-10 pounds. For in-line cervical immobilization, the head was manually stabilized by grasping the mastoid processes bilaterally to limit movement throughout the intubation sequence without application of traction. Of the sixteen subjects, five were only stabilized with traction and not manual immobilization. Eleven subjects were stabilized by both methods.

After completion of the intact cervical intubation series, each subject was placed in a prone position and a midline cervical incision was made. The C4-5 level was identified with fluoroscopy and the supraspinous, interspinous, facet ligaments, posterior longitudinal ligament and ligamentum flavum were incised with a scalpel blade. The facets were bilaterally dislocated following the ligamentous disruption to verify the degree of instability. The facets were then reduced. The wound was closed following destabilization.

In all cases, the entire laryngoscopy and intubation sequence was monitored and recorded with continuous lateral fluoroscopy of the cervical spine. The occipital base through C5 was visualized and the head maintained contact with the table at all times throughout the sequence. Cervical segments caudal to C5 could not be consistently visualized due to the shoulders. Fluoroscopic images were recorded on a VHS-formatted video recorder interfaced with the fluoroscopy machine.

Data Processing

Video images were digitized using a frame grabber, either IP Lab Spectrum version 2.3.1e (Signal Analysis, Vienna, Virginia) or Flashpoint version 4.0 (Integral Technologies, Indianapolis, Indiana). The digitized 640x480 grayscale images were analyzed using freely available image analysis software. On a Macintosh computer, NIH Image 1.55 or 1.61 was used (The National Institutes of Health, Bethesda, MD available over the internet by anonymous FTP from ftp://zippy.nimh.nih.gov/pub/nih-image). On a PC-compatible, UTHSCSA ImageTool 1.27 was used (developed at the University of Texas Health Science Center at San Antonio, Texas and available over the internet by anonymous FTP from ftp://maxrad6.uthscsa.edu).

Each intubation sequence was digitized at five distinct stages: (1) **Baseline** denoted by the head and neck in neutral position prior to any manipulation or insertion of the laryngoscope, (2) **L1** at first appearance of the laryngoscope in the glottis, (3) **L2** after the laryngoscope was advanced into the vallecula and a ventral lifting force was applied to its maximal excursion prior to passage of the endotracheal tube, (4) **Tube** when the endotracheal tube passed through the vocal cords, and (5) **Post** after the laryngoscope was removed and the head and neck came to their final resting positions.

Segmental anterior-posterior translation was always less than 1 mm; thus, angular changes were used to compare subjects. The angular position of each segment, occiput through C5, was measured at the five stages of the intubation sequence. Two reproducible bony reference points were chosen for each segment that remained constant for that intubation sequence. The line created by intersecting each set of reference points was then referenced to either the horizon or vertical, depending on its absolute position in space, such that forward rotation of the segment would increase the angular measurement and backward rotation would decrease the angular measurement. The horizontal/vertical line remained constant during that intubation sequence. Reproducibility with this technique is very good as previously published[20] with an average intraobserver variability of 0.37° and an average interobserver variability of 0.48°.

Angular values were referenced to baseline and these changes from baseline were used for comparison. Our cervical motion data, as well as that of two other publications,[9,12] were not distributed normally. Thus, nonparametric Wilcoxon signed-rank test was used to determine significant paired-differences between angular measurements. The intact series without stabilization was compared to previously published live patient data at each stage and level. To assess motion independent of direction, the absolute value of the greatest angular movement for each cervical level during the intubation sequence was used for comparison. Thus, for example, two degrees of flexion would not be considered different from two degrees of extension as this represents a change in the direction of movement without a change in the amount of movement. A probability value of less than 0.05 was considered significant.

Results

Movement of the intact spine during orotracheal intubation is characterized mainly by extension at all levels during all stages except minor flexion at some levels during L1. The greatest motion occurred at the craniovertebral junction, followed by the atlantoaxial junction. Motion decreased sequentially at each more caudal interspace. The greatest movement occurred during the L2 and Tube stages (Fig. 1). These results are statistically indistinguishable from the results in living subjects.[20]

During orotracheal intubation, the injured spine experienced the greatest motion at the craniovertebral junction followed by the atlantoaxial junction. The predominant motion was extension at all levels except at the destabilized C4-5, where intubation caused flexion (Figs. 2, 3) instead of the extension produced in the intact spine.

Traction significantly reduced craniovertebral junction motion in both the intact as well as the injured spines. In the intact spine (Table 1), craniovertebral junction motion decreased from 8.8° to 4.9° ($P<0.05$). In the injured spine (Table 2), motion decreased from 7.3° to 5.3° ($P<0.05$). Traction did not significantly reduce motion at any other level. Manual in-line cervical immobilization did not significantly limit motion at any level during intubation.

There was a trend toward decreased C4-5 motion with both forms of stabilization in the intact spine (Table 1) and increased motion with both forms of stabilization in the injured spine (Table 2), although these differences were not statistically significant.

Discussion

We were very pleased to complete a study of 16 subjects when we had anticipated only evaluating six cadavers. We chose to examine the ligamentous injury prior to evaluating the bony injury. The rationale for this decision is based on the concern that the bony facet injury will be associated with at least some ligamentous injury and therefore it was deemed more appropriate to study the "pure" ligamentous injury first. This is the first study to compare cervical motion of orotracheal intubation in cadavers with that of living patients. The motion measured in cadavers accurately reflects that found in living patients[20] in both character and degree.

Two previous studies, one by Hastings and Wood[13] and a second by Majernick et al[18], reported that immobilization reduced head extension and craniovertebral junction motion, respectively. Hastings found no significant reduction in motion using traction. Both studies measured motion of intact spines, but the methods used in both studies to measure motion differed greatly from ours.

Hastings and Wood[13] used an angle finder attached to the head to estimate cervical motion during intubation. In a second paper[12] in which immobilization was not used, Hastings et al statistically validated the angle finder as accurately reflecting overall cervical extension by comparison to measurements from static radiographs. Angle finder motion directly reflects head movement which, when allowed to move freely, may reflect cervical movement, but when head movement is restricted the angle finder may only reflect the ability of immobilization to restrict head motion, not craniovertebral junction motion. Traction may not immobilize the head necessarily, but may limit motion of the craniovertebral junction which may be missed by only measuring head movement with an angle finder. The method of traction employed in Hastings' study (manual) is also different from ours (Gardner-Wells), and he did not measure the force of traction. Gardner-Wells tongs provide for a more secure method of traction than grasping the head during intubation. These variations in methods may account for the differences in results between our work and that of Hastings and Wood.

Majernick et al[18] measured motion during intubation using static radiographs but did not measure angular changes. Instead, these investigators measured two parameters termed $\Delta C_{1\text{-}0}$ and $\Delta C1+C5$ and used the combination of the two for comparison between stabilization methods. $\Delta C_{1\text{-}0}$ was the change in the distance between the inferior spinous process of C1 and the occiput. $\Delta C1+C5$ was the combination of changes in the anterior-posterior distance of C1 and C5 measured when C3 was superimposed on two successive static radiographs. Although these measurements reflect some type of motion, they do not directly reflect angular motion. Intubations were not paired, so no direct comparison between motion with and without immobilization was made in the same patient. Finally, the number of subjects examined was very small, only four subjects were immobilized during intubation.

This study characterizes segmental cervical motion during orotracheal intubation with a posterior ligamentous C4-5 injury and shows a change in direction of movement from extension to flexion at the unstable level. Our findings are unique in that we have documented the inability of manual in-line cervical immobilization and traction to limit this motion. In fact, motion at C4-5 tended to increase with both forms of stabilization. There is ample evidence in the literature of no increased neurologic injury resulting from orotracheal intubation with immobilization in patients with cervical injuries.[11,14,21,22] Although immobilization and traction insignificantly increase motion of C4-5 during intubation with a posterior-ligamentous injury, their effect on more rostral injuries is not known. Bivins[3] showed that traction causes significant distraction in patients with atlanto-occipital dislocations, Hangman's fractures and C6-7 fracture dislocations. Although traction effectively reduces craniovertebral junction motion during intubation in the uninjured spine, its efficacy in the presence of a craniocervical junction injury is not known.

Finally, as our study shows, caution must be exercised in evaluating the effect of stabilization on motion in the intact cervical spine and extrapolating to the unstable spine. Ability to limit motion of a stable level does not necessarily imply reduction of motion of an unstable level.

PATIENT STUDY

Experimental Methods

Four human subjects were studied. The preoperative clinical exam included a detailed spinal history and examination. The demographics of these patients and the airway assessment are shown in Table 3. Although some patients were undergoing surgery for cervical disc disease, the upper cervical spine (occiput to axis) and the subaxial spine to C5 were clinically and radiographically normal. Motion in flexion and extension was radiographically within the normal range. The airway of each subject was assessed using the Malampati system.[19]

Each patient was given a general anesthetic and ventilation maintained with a mask. Gardner-Wells tongs were applied in the usual fashion. A standard intubation with a MacIntosh blade was performed without traction. Following this intubation the endotracheal tube was removed and ventilation was again achieved by masking. In-line traction was administered manually using Gardner-Wells tongs by the principal investigator. This was done by pulling on a spring gauge which was attached to the tongs. The amount of traction delivered was determined by the principal investigator and based entirely on clinical judgement. An observer noted the reading on the spring gauge which was consistently in the range of 10-12 pounds. The patient was intubated while the traction was applied. The ease of intubation was assessed by the anesthesiologist. The optimal airway view was scored according to Cormack.[4] The Malampati Grade, ease or difficulty of intubation, and Cormack scores for each patient are listed in Table 4.

All intubations were performed under continuous fluoroscopic monitoring. The fluoroscopic images were recorded on a VHS-formatted video recorder interfaced with the fluoroscopy machine and digitized as previously described. There was less than 1 mm of anteroposterior translation at each motion segment. The segmental angular motion was determined as previously described.

Results

The motion data for the four patients is graphically displayed in Figures 4 and 5. The motion of the cervical spine during intubation without traction was similar to that described earlier in this report and in our previous publication.[20] Hand-held traction altered the motion characteristics of the cervical spine during intubation as compared to the freely mobile spine. Specifically, motion across the O-C1 segment decreased by about 2° at the L2 and Tube phases. Motion at the C1-C2 level during these phases decreased 4° and 3°, respectively. The greatest change occurred at the C2-C3 segment where almost no motion occurred throughout the entire intubation process. There was a slight decrease in motion at C3-C4 during the tube phase only. There was little motion detected at C4-C5 accounting for about a 2° difference in most phases of intubation as compared to the nontraction condition. Overall, the effect of traction on cervical spinal motion during intubation in live patients was almost identical to that noted in our cadaveric study.

Because only 4 patients have been studied, statistical analysis of the data has not yet been performed.

Discussion

It was anticipated that ten patients would be evaluated in the first arm of the patient study and this would be completed in one year. We have only been able to accrue 4 patients. Subject enrollment fell short of expectations due to unforeseen internal problems in working out the administrative logistics for actually performing the intraoperative fluoroscopy. The first subject was not enrolled until late June. We believe that enrollment will improve and we expect to finish the first two arms of the patient study as outlined in the Body of the Research Proposal.

The cervical motion of the non-traction subjects was similar to the motion we have previously reported. Traction decreased motion in all phases of intubation as compared to the non-traction condition. This decrease was greatest at the junction between the upper and lower cervical spine, C2-C3 and at the most caudal recorded level of the subaxial cervical spine (C4-C5). The data compare very favorably with the data from the above reported cadaver study.

We were unable to visualize the vocal cords well enough to safely intubate subject #3 while traction was being administered. The non-traction intubation was graded as easy. It is notable that although the Malampati grade of this individual was only II, all other subjects had a score of I. This is a potentially significant finding in that a higher grade Malampati score may be predictive of intubation difficulty in traction. If this finding is borne out, then alternative means of securing the airway other than orotracheal intubation may need to be considered in individuals in cervical traction.

CONCLUSIONS

CONCLUSIONS FROM CADAVERIC STUDY

Traction reduced craniovertebral junction motion in the intact spine, but neither traction nor manual in-line cervical immobilization limits motion at C4-5 with a posterior-ligamentous injury. Although this study does not substantiate the efficacy of immobilization during orotracheal intubation, neither does it warn against its use as its effect on other cervical injuries has not been studied.

CONCLUSIONS FROM PATIENT STUDY

Accurate data was collected from four patients. These data suggest that traction decreases motion in all cervical segments. The decrease affects the C2-C3 and C4-C5 levels the greatest. The Malampati grade may be able to predict difficulty in performing orotracheal intubations while traction is being administered.

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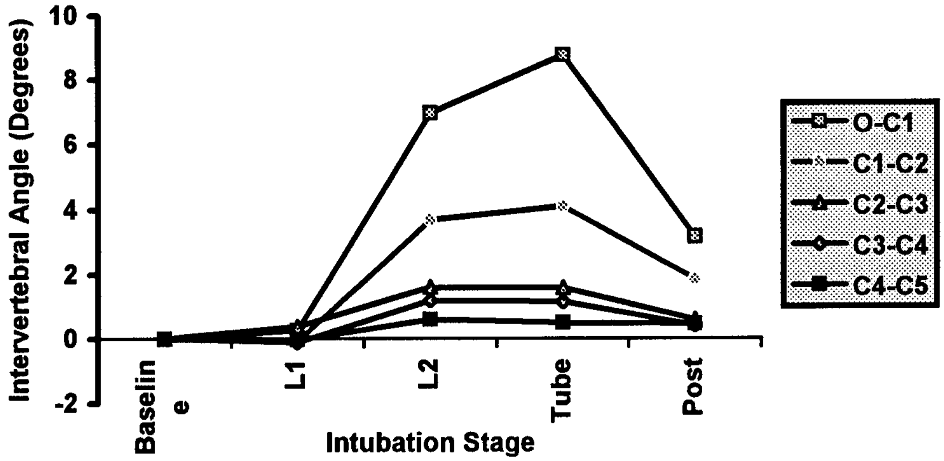
LEGENDS

Figure 1	Graph comparing median values of motion experienced during each stage of cadaveric intubation for levels O-C1 through C4-5. Positive numbers represent degrees of extension and negative numbers degrees of flexion.
Figure 2	Graph comparing median values of greatest motion experienced during the cadaveric intubation sequence for levels O-C1 through C4-5 with no stabilization, traction and immobilization in the intact spine. Positive numbers represent degrees of extension and negative numbers degrees of flexion.
Figure 3	Graph comparing median values of greatest motion experienced during the intubation sequence for levels O-C1 through C4-5 with no stabilization, traction and immobilization in the injured spine with a destabilized C4-5 segment. Positive numbers represent degrees of extension and negative numbers degrees of flexion.
Figure 4	Graph comparing median values of motion experienced during each stage of non-traction patient intubation for levels O-C1 through C4-5. Positive numbers represent degrees of extension and negative numbers degrees of flexion.
Figure 5	Graph comparing median values of motion experienced during each stage of traction patient intubation for levels O-C1 through C4-5. Positive numbers represent degrees of extension and negative numbers degrees of flexion.
Table 1	Median values of absolute greatest angular motion (degrees) in the intact spine at levels O-C1 through C4-5 with no stabilization, traction and immobilization. Statistically significant values are indicated in bold.
Table 2	Median values of absolute greatest angular motion (degrees) in the injured spine at levels O-C1 through C4-5 with no stabilization, traction and immobilization. Statistically significant values are indicated in bold.
Table 3	Subject Demographics
Table 4	Malampati and Cormack scores for individual patients and specific events.



Intervertebral Angle (Degrees)
10
8
6
4
2
0
-2
Baseline
L1
L2
Tube
Post
Intubation Stage
O-C1
C1-C2
C2-C3
C3-C4
C4-C5

FIGURE 1

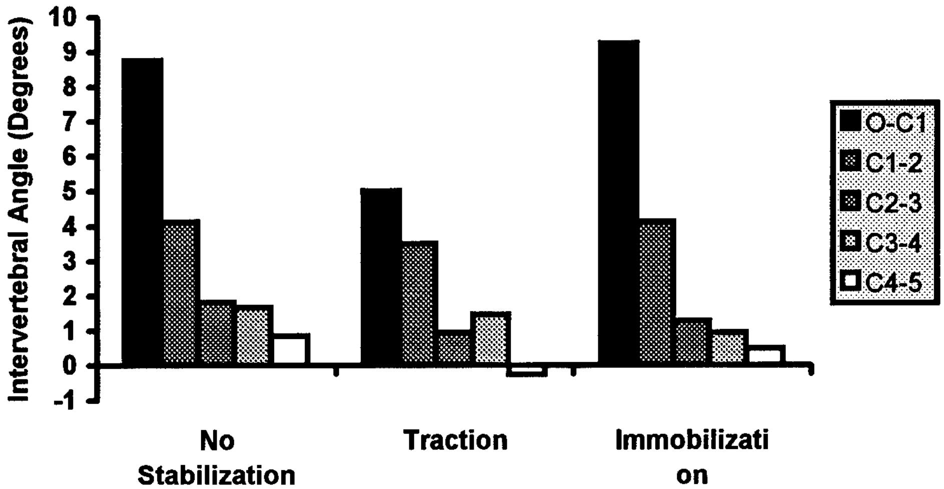

Intervertebral Angle (Degrees)
10
9
8
7
6
5
4
3
2
1
0
-1
No Stabilization
Traction
Immobilizati on
O-C1
C1-2
C2-3
C3-4
C4-5

FIGURE 2

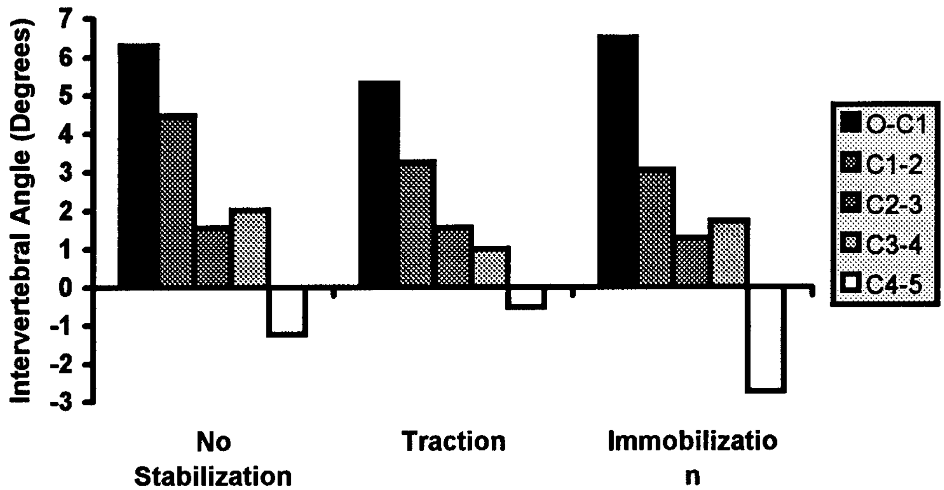

Intervertebral Angle (Degrees)
7
6
5
4
3
2
1
0
-1
-2
-3
No Stabilization
Traction
Immobilization
O-C1
C1-2
C2-3
C3-4
C4-5

FIGURE 3

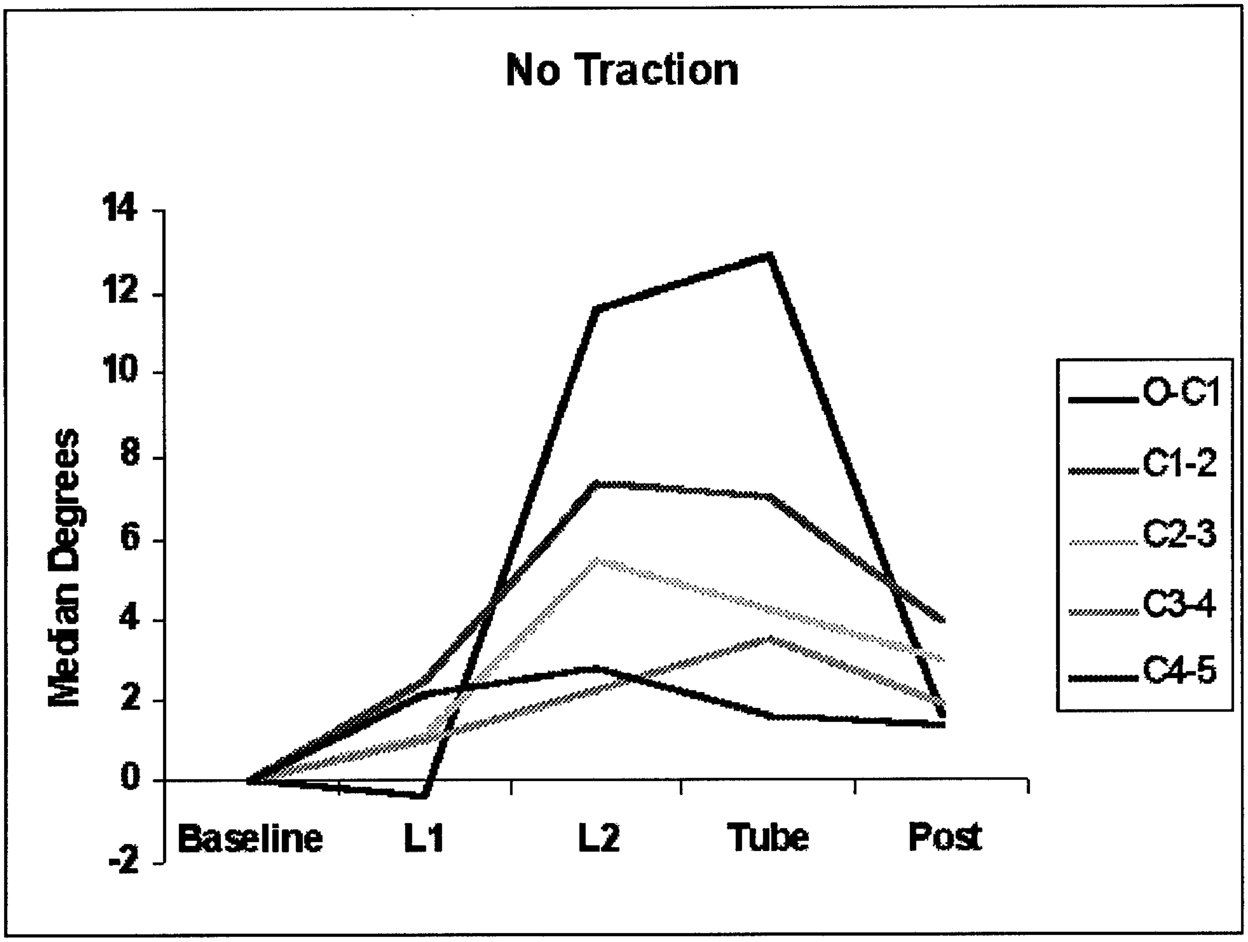
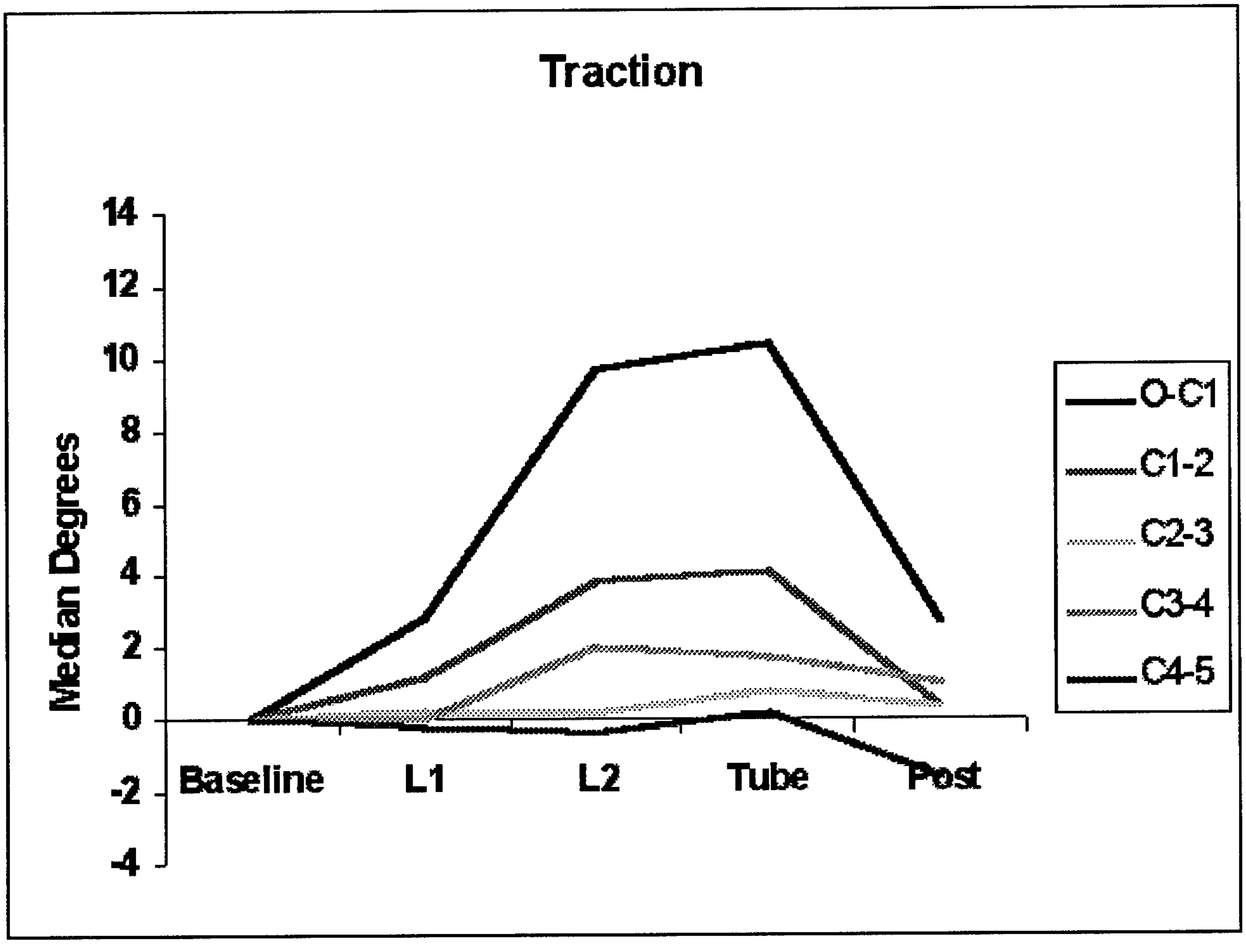

No Traction
Median Degrees
14
12
10
8
6
4
2
0
-2
Baseline
L1
L2
Tube
Post
O-C1
C1-2
C2-3
C3-4
C4-5

FIGURE 4



Traction
Median Degrees
14
12
10
8
6
4
2
0
-2
-4
Baseline
L1
L2
Tube
Post
O-C1
C1-2
C2-3
C3-4
C4-5

FIGURE 5

TABLE 1

Level	No Traction	Traction	Immobilization
O-C1	**8.8**	**4.9**	9.3
C1-2	4.1	3.5	4.1
C2-3	1.8	1.7	2.2
C3-4	1.9	1.9	2.4
C4-5	2.1	1.2	1.9

TABLE 2

Level	No Traction	Traction	Immobilization
O-C1	**7.3**	**5.3**	6.8
C1-2	4.5	3.3	3.1
C2-3	1.6	1.7	1.7
C3-4	2.0	1.6	1.7
C4-5	1.8	2.2	2.8

TABLE 3

Subject Number	Sex	Age (years)	Height (feet)	Weight (pounds)
1	Female	46	5.5	187
2	Male	59	5.7	185
3	Male	45	5.5	200
4	Male	50	5.8	285

TABLE 4

Subject Number	Malampati	Mask Ventilation	1st Laryngoscopy, view (Cormack)	2nd Laryngoscopy, view (Cormack)
1	I	easy	easy, I	easy, II
2	I	easy	easy, II	easy, II
3	II	easy	easy, I	difficult, III
4	I	easy	easy, I	easy, I